

The establishment of an American butterfly in the Arabian Gulf: *Brephidium exilis* (Boisduval, 1852) (Lycaenidae)

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Abstract. This paper documents the successful establishment and spread in the Arabian Gulf of the North American butterfly *Brephidium exilis* (Boisduval, 1852) (Lepidoptera: Lycaenidae). First recorded from Sharjah in 1995, it can now be found throughout the United Arab Emirates, in northern Oman and in eastern Saudi Arabia feeding on exotic as well as native Chenopodiaceae and Aizoaceae. The possible mode of entry into the region is discussed, as is the potential final range.

Key words. Lepidoptera, Lycaenidae, *Brephidium exilis*, introduced species, invasive species, spread, geographical distribution, establishment, United Arab Emirates, Oman, Saudi Arabia, host plants, Chenopodiaceae, Aizoaceae.

Introduction

In November 1999, Larsen [then in Manila] received an e-mail from Legrain, who had just returned from the United Arab Emirates (UAE). He had caught a tiny Lycaenid that could not be identified from existing works on Arabian butterflies (Benyamini 2002; Brown 1992; Larsen 1974, 1982, 1983, 1984, 1990; Larsen & Larsen 1980; Pittaway 1979, 1980, 1981, 1985; Walker & Pittaway 1987; Wiltshire 1957, 1964). He thought it might belong to the genus *Brephidium* Scudder, 1876, a taxon known only from South Africa and the Sonoran dry zone of Mexico and the USA. A good photograph was attached to the e-mail. Larsen was convinced it was a species new to the region, and that nothing like it occurred in the Oriental Region.

At the same time Legrain also contacted Gillet in the UAE. He knew the butterfly well, identifying it as the Western Pygmy Blue (*Brephidium exilis* (Boisduval, 1852)), a common butterfly in southern California, Arizona and Texas; he had even written a small note for a local newspaper about its discovery at Al-Ain in 1998. Larsen contacted Pittaway, who was of the opinion that the species had probably been imported along with exotic plants from North America. Larsen (2000, 2004) documented its presence and asked – ‘What was it doing in the Emirates?’

In 2005, when Weidenhoffer contacted Larsen with a 2004 record of *B. exilis* from eastern Saudi Arabia, it became evident that the colonization of the Arabian Gulf by this alien butterfly had never been properly documented.

Such firm establishment of exotic butterflies is a very rare event. There are not more than 20–30 similar cases – and there are more than 18,600 recorded butterfly species worldwide (Larsen 2005).



Fig. 1. Halophyte-dominated breeding locality for *B. exilis*, ‘Half Moon Bay’, 15 km SW Dhahran, eastern Saudi Arabia (Photo: J. Majer).

Present distribution in the Arabian Gulf

The butterfly seems to be quite common – though local – in the UAE and northern Oman, particularly in and near urban areas in association with *Sesuvium verrucosum*. In February 2004, further examples were collected by J. Majer from farther north, near Dhahran and Al Qatif, Saudi Arabia.

The Dhahran locality was a small sandy coastal strip with tufts of halophytic plants at ‘Half Moon Bay’, 15 km southwest of Dhahran (Fig. 1). At 14.00h, in strong sunshine and with the temperature around 30°C, *B. exilis* was the only butterfly present, either sitting inside the tufts or flying just above the ground around the plants. When disturbed they took refuge inside the plants and were very difficult to catch. Six specimens were secured – 5 males and 1 female.

One week later Majer collected one male 3 km west of Al Qatif (15 km northwest of Dammam) on a sandy strip between embankments of oil pipelines partly covered with grass, small yellow-bloomed flowers and several bushes (Fig. 2). Also present were *Spialia doris doris* Walker, 1870 (the first record for eastern Saudi Arabia), *Colias crocea* (Geoffroy, 1785) and *Cynthia cardui* (Linnaeus, 1758).

In another recent reference Jongbloed (2003) writes: “It [*B. exilis*] is a very small, but very beautiful butterfly that can be observed in large numbers around the *Sesuvium verrucosum* plants that grow profusely on the dumpsite near the American University of Sharjah”.



Fig. 2. Locality for *B. exilis*, 3 km west of Al Qatif, eastern Saudi Arabia (Photo: J. Majer).

Specific details are: **UAE:** Ajman (April 1999 (A. Legrain)), Al-Ain (April 1998 (M. Gillet)), Dubai (M. Gallagher; G. Feulner), Das Island (R. Western), Fujairah (April 2000 (A. Legrain)), Merawah Island (M. Gallagher), Sharjah (5–7 December 1995 (E. Rutjan); (M. Jongbloed); 1998 (A. Legrain); April 1999 (A. Legrain)); **OMAN:** Buraimi & Mahdan (M. Gallagher); **SAUDI ARABIA:** Dhahran (26°10'N 50°00'E, 13 February 2004 (J. Majer)); Al Qatif (26°32'N 49°59'E, 20 February 2004 (J. Majer))

Pittaway (1979, 1980, 1981) is almost certain that he could not have overlooked this butterfly during his extensive collecting in eastern Arabia. Brown (1992) did not record it from the UAE. Given that the first records are from 1995 and that the present range is relatively limited, the establishment of *B. exilis* in the region probably took place sometime during the early 1990s.

Native range of *B. exilis*

This species – the smallest butterfly in North America – is a native resident of the dry regions stretching from the southern USA (Texas, New Mexico, Arizona, Nevada, California) down through Mexico and Belize (Jan Meerman, pers. comm. 2005) to Venezuela. It is also found on many Caribbean islands, such as the Bahamas, Cuba, Grand Cayman, Jamaica, Hispaniola, the Turks & Caicos, Aruba and Bonaire (Riley

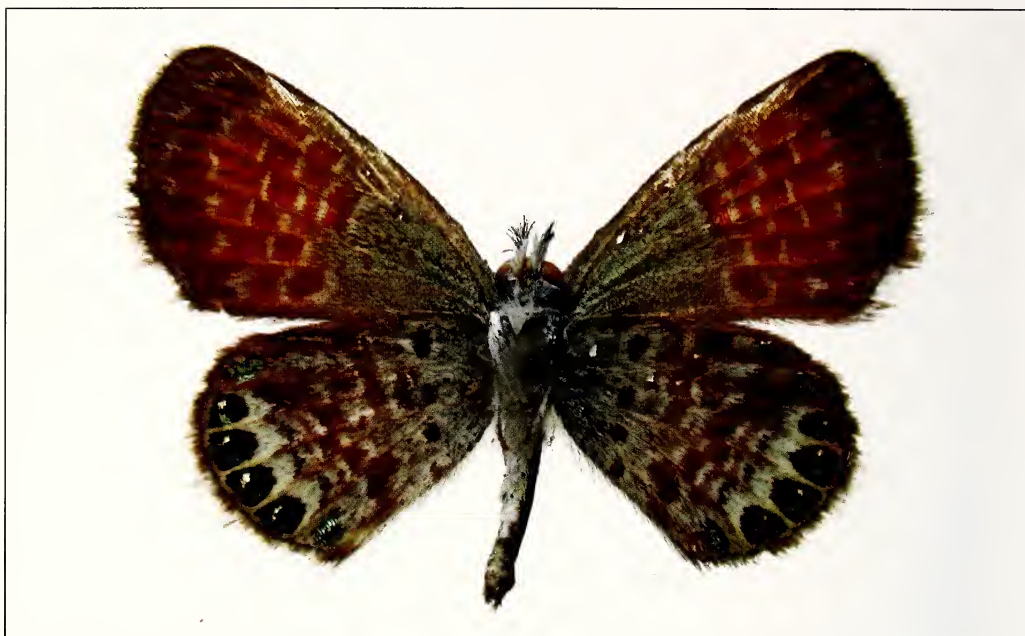


Fig. 3. Underside of *B. exilis*, Dhahran, Saudi Arabia (Photo: Z. Weidenhoffer).

1975; Miller, Debrot & Miller 2003). Around 1979 it was accidentally introduced into Hawaii, where it seems to be thriving (on introduced host plants).

In the USA this species also ranges (apparently as a wind-blown summer migrant) north to south-eastern Oregon and southern Idaho, and east to the prairie areas of Nebraska, Arkansas, and Missouri (Pyle 1981); however, the full status of these northern populations needs further study.

There is some confusion, however, as to the status of the *Brephidium* species found in the south-eastern USA, namely *B. isophthalma* (Herrich-Schäffer, 1862). *Lycaena pseudofoea* was described by Morrison in 1873 (without figures) from three specimens collected at Key West, Florida, where it is a local, but common, butterfly. However, its proper taxonomic status is still unsettled. Scott (1986) treats *pseudofoea* as a subspecies of *Brephidium exilis*. Calhoun (1997) treats *pseudofoea* as a subspecies of *B. isophthalma*, but states that it may be a subspecies of *B. exilis*. Opler & Krizek (1984) treat *B. i. pseudofoea* and *B. exilis* as separate species. Pavulaan & Gatrell (1999) are of the opinion that all these taxa are probably part of the same species – *B. exilis*. We are grateful to B. Walsh of the University of Arizona for confirming that Arabian material conforms to that of typical *B. e. exilis*.

Ecology and habitat preferences

Although it can be found in deserts and prairies in North America, the Western Pygmy Blue is most abundant in lowland coastal areas rich in halophytic *Chenopodiaceae*,

such as washes, salt marshes, alkali flats, railroad tracks, disturbed places and vacant lots (Pyle 1981). Such habitats are also common in the Arabian Gulf. In California it ranges across San Diego County wherever the alien *Atriplex semibaccata* is to be found; however, although the larval host plants in coastal California are primarily *Atriplex* and *Sueda*, *Salsola* is more typically utilized farther inland during the summer months.

In the Turks & Caicos it is most commonly found in marshy areas in association with the low-growing succulent *Trianthema portulacastrum* (Aizoaceae). On Jamaica it has been reported as utilizing *Batis maritima* (Riley 1975) – a possibly erroneous record as this species belongs to a totally unrelated family and order of plants (Capparales: Bataceae) than do its other hosts.

This butterfly is almost always seen fluttering weakly about one of the low-growing larval host plants in a manner similar to *Chilades trochylus* (Freyer, 1844). Even though the species often occurs in large numbers, many people probably walk right by these delicate blues because of their tiny size and dainty, low-to-the-ground flight (Pyle 1981).

This is one butterfly whose populations have probably increased greatly in North America since the coming of Europeans and the introduction of alien weeds (such as tumbleweed (*Salsola* spp.)), which have been utilized to a great extent as larval host plants (Graves & Shapiro 2003). This rapid spread and exploitation of new hosts has no doubt been aided by the ability of *B. exilis* to disperse using strong summer winds and weather fronts – a mechanism used by other desert species in many parts of the world – to found new, if mainly ephemeral, colonies, e.g. *Anaphaeis aurota* (Fabricius, 1793) (Pittaway 1980, 1985). Many of the populations established in new areas during the summer months die out with the onset of winter as their annual host plants die, or the weather gets too cold, or the habitat floods (Thacker 2004).

Biology and life history

The Western Pygmy Blue is a small butterfly, with a wingspan of 10–15mm. The upper side is chocolate-brown, with blue shading at the base of the white-fringed wings. Underneath, the wings are grey-brown, blending to bluish-grey at base. The forewing underside is shaded with orange across the outermost half; the hind wing is marked with brown patches in the middle and is edged marginally with a row of small iridescent blue-green centred black spots; there are whitish striations across the wings (Fig. 3). Females are larger than males and less blue on the upper side.

Males actively patrol for receptive females. The latter lay their blue-green eggs singly on all parts of the host plant, with most placed on the topsides of leaves and near flowering stems. These hatch into light green caterpillars; however, larval coloration can vary, but generally it is yellowish green to tan and shaded or striped with yellow on the back and sides. Alternatively, it may be green, shaded or striped with dark green or dark pink, or it may be green with a dark coloured head and lacking stripes altogether. Often it is covered with brownish or whitish bumps. Its average, full-grown length is 11mm.

This species has no diapause and continues breeding throughout the year where resident (Thacker 2004).

Larval hosts plants

Caterpillars eat the leaves, flowers and fruits of many Chenopodiaceae and Aizoaceae, including goosefoot (*Chenopodium* spp.), orache/saltbush (*Atriplex* spp.), glasswort (*Salicornia* spp.) and *Sesuvium* spp. (Pyle, 1981)

In the USA it has been recorded from *Atriplex canescens*, *A. coulteri*, *A. serenana*, *A. leucophylla*, *A. patula*, *A. patula* var. *hastata*, *A. semibaccata*, *A. rosea*, *A. cordulata*, *A. hymenelytra*, *A. lentiformis* var. *breweri*, *Suaeda fruticosa*, *S. californica*, *S. moquinii*, *S. torreyana*, *Salicornia virginica*, *Chenopodium album*, *C. leptophyllum*, *Salsola iberica*, *S. kali* var. *tenuifolia*, *Halogeton glomeratus*, *Tetragonia tetragonioides*, *Trianthema portulacastrum* and *Sesuvium verrucosum*. A fuller list is given by Shapiro (1973).

The most important host in the USA is the fourwing saltbush (*Atriplex canescens* (Pursh.) Nutt.). This shrublet is the most widely distributed native woody plant in North America, its native range extending north-south from southern Alberta to central Mexico and east-west from the Missouri River to the Pacific Coast. It is widely planted in temperate regions of North America as an ornamental, and has become locally naturalized east of the plains grasslands (its native boundary). In the Sonoran deserts, fourwing saltbush may dominate or co-dominate salt-desert scrublands and alkali flats.

This shrub has been planted worldwide (as has the Australian *A. semibaccata*) to increase forage production on arid rangelands. It has become naturalized in deserts and arid regions throughout the world, including many Arabian Gulf states.

Many countries around the Gulf have extensive areas of salt-desert scrublands and alkali flats dominated by numerous native and alien Chenopodiaceae and Aizoaceae. Thus the potential host plants in the Gulf are several species of *Anabasis*, *Atriplex*, *Arthrocnemum*, *Bienertia*, *Chenopodium*, *Halopeplis*, *Salsola* and *Suaeda*, as well as *Sesuvium* and *Trianthema* (Collenette 1985; Al-Turki, Omar & Ghafoor 2000). The genus *Salsola* is particularly well represented.

Possible mechanism of introduction into the UAE

Two possible routes of introduction are envisaged. The first – and least likely – is that one of the many US expatriates working in the UAE brought back some ‘infested’ ornamental succulents from Texas/Arizona/California to brighten up their garden.

The other, and much more likely scenario, is that this butterfly was introduced by accident during one of the many documented trials of North American halophytes as potential fodder plants or for degraded land reclamation (Khan 1981; Riley 1989; Glenn et al. 1994; Lieth & Al Massoum 1991–1992; Dakheel, Alhadrami & Peacock 2001; Peacock et al. 2002).

Land reclamation and fodder plant projects in the UAE

Starting in the 1970's, it was realised by the UAE governments that something needed to be done about the severe overgrazing and land degradation afflicting the region. Khan (1981) reviewed the progress of several afforestation and agricultural develop-

ments during 1975–80. Forest areas managed by the Forest and Agriculture Departments were extensively interplanted with fodder shrubs such as *Atriplex*.

In 1990 an international symposium was held at the UAE University in order to draw together the worldwide experience in this field (Lieth & Al Massoum 1991–1992). Parallel to this activity, Mr. Armin Lieth was asked to collect a large number of halophytic species in the Caribbean and trial them in the UAE desert environment. Some scientists invited to participate in the above mentioned symposium were also asked to provide plant material (see Lieth & Al Massoum (1991–1992) for more detail). A quarantine station was erected near Mussafah from where the surviving specimens were later transferred to an experimental farm near Nahshallah.

The International Atomic Energy Agency (IAEA) initiated a multinational project in 1997 – known as the ‘Sustainable Utilization of Saline Groundwater and Wastelands for Plant Production’ – in order to introduce and domesticate halophytes for commercial crop production throughout North Africa and the Middle East. This project was subsequently expanded to include large tracts of ‘wasteland’, new species and other regional habitats throughout Africa and the Middle East. Several species of *Atriplex* were an important component.

In 1999 the International Centre for Biosaline Agriculture (ICBA) was established at Dubai. Its brief was to develop sustainable management systems to irrigate food and forage crops (and ornamental plants) with saline water and to provide a source of salt-tolerant plants for socio-economic development in arid and semi-arid areas.

Wakabayashi (2000) gives details of a major project to use seawater as irrigation for halophyte plantations on the Arabian Peninsula. Planting halophytes was proposed as a way to re-establish vegetation along the periphery of the Rub Al Khali desert and the coastline of the UAE. The five species suggested as most suitable were *Batis maritima*, *Atriplex canescens*, *Salicornia bigelovii*, *Suaeda esteroa* and *Sesuvium verrucosum*.

Peacock et al. (2002), outlined research undertaken to identify forage halophytes that were tolerant of saline soils, with research sites being located in Oman, in the UAE and at the ICBA in Dubai. Research at the UAE University in Al-Ain looked at the salt tolerance of several *Sporobolus* and *Atriplex* species.

The pan-tropical *Sesuvium portulacastrum* has been extensively used throughout the Arabian Peninsula in landscaping and land reclamation projects since its first introduction to Abu Dhabi in 1989 (Böer 2002). It has become widely naturalized and its presence has probably aided the establishment and spread of *B. exilis*.

Including the above, a large number of halophyte research and development projects have been carried out in the Arab Gulf States over the last 25 years, mainly in the UAE (in particular Abu Dhabi and Dubai) and Saudi Arabia. These projects involved exotic and indigenous species. Most of these projects imported plants directly from North America for evaluation (Böer 2002).

Potential new range of *B. exilis*

The overall climate of the UAE is subtropical, warm and arid. Midday air temperatures range between 35° and 50°C from May to October, and from 20° to 35°C during the

winter months. In the desertic interior the highest ground temperatures during summer reach 70°C, but may fall to freezing in winter. The average rainfall over the Emirates is less than 100 mm per annum, but this is very spasmodic and up to 50% of the annual total may fall in a single day. Some monsoon-like showers are also received during the summer months on the east coast, and in the mountain belt which forms the watershed between the Arabian Gulf and the Gulf of Oman. Moisture also condenses in the form of fog and dew, especially along the coastal belt. Strong winds and sand storms are common throughout the Emirates, being especially frequent and severe in summer. Sand dunes are a dominant landscape feature. These conditions are very similar to those found across much of the natural North American range of *B. exilis*.

Soils are generally coarse, sandy and undeveloped. They are deficient in organic matter, nitrogen, available phosphorus, and trace elements such as zinc, iron and manganese. Non-calcareous soils may also be deficient in potassium. Soils in the 'subkha' coastal belt and low-lying depressions in the interior of the desert are highly saline.

To a greater or lesser extent, these conditions can be found across the arid regions of North Africa and into Spain, parts of eastern Africa, the Levant and Arabian Peninsula, southern Iran and large areas of India. This is thus the potential range of *Brephidium exilis*. Benyamini (2000) predicts it will reach Israel in the near future.

Biogeography of *Brephidium*

There is a very similar species to *B. exilis* resident in southern Africa, namely *B. metophis* (Wallengren, 1860) (confined to South Africa, Namibia, Botswana, Mozambique and Zimbabwe). The genitalia and external features show clearly that they belong to the same genus. Another related taxon, namely *Oraidium barberae* (Trimen, 1868) (which also has very similar genitalia), is also endemic to South Africa. This New World/Old World distribution is odd, but not unknown for other plant and animal taxa.

H. Stempffer (discussions with Larsen 1974) considers *Brephidium* to be a true Gondwanaland relict genus, its evolution preceding the split up of Africa, Antarctica and South America. This reflects the thoughts of Miller & Miller (1997), who believe that some Biblidinae from the island of Hispaniola in the Caribbean are so close to African species as to indicate a common Gondwanaland origin. In the same paper they also make the comment – "A similar situation exists [in the Lycaenidae] where one genus, *Brephidium*, is represented in both hemispheres and its sister genus, *Oraidium*, in southern Africa ... these butterflies are not vagile and their intercontinental dispersal is highly unlikely." Clench (1963) also comments on this African/New World connection. However, in the absence of supporting molecular data this Gondwanaland hypothesis remains pure conjecture. Butterflies as a whole appear to be mid- to late Cretaceous in origin. Whether a Polyommata genus is as old as the Africa/Americas split is debatable. As *B. exilis* exhibits what is known as 'waif dispersal' (a form of wind dispersal), the trans-Atlantic split in the genus may well have occurred some time in the Tertiary when the Atlantic Ocean was more narrow. This discussion need not concern us here, but it would be very interesting to observe the interaction of

B. exilis with *B. metophis* should the former reach southern Africa. Considering its ecology and method of dispersal, this is not an impossibility.

Discussion

From the data we have it seems clear that the Sonoran butterfly, *Brephidium exilis*, has irreversibly established itself in the Arabian Gulf on exotic as well as native hosts since its probable introduction in the early 1990s, and that there is a very real possibility that it will spread farther. The introduction and use of several known New World host plants in landscaping and land reclamation projects has facilitated this, and may have even been the route of entry. Although a number of such establishment events are known, it is never-the-less a very rare occurrence. There are some 18,600 butterfly species worldwide and only a few have managed to establish themselves away from their natural ranges.

There are several ways in which this has occurred, nearly all of them human-assisted. The introduction and use of host plants beyond their natural ranges can facilitate natural range expansion in butterfly species which can utilize those plants. This has occurred in North America with *B. exilis*, which utilizes both native and exotic weeds. Graves & Shapiro (2003) and Thacker (2004) have documented the use of many alien hosts in California by native butterflies, including *B. exilis*. Another good example is the natural spread of *Danaus plexippus* (Linnaeus, 1758) across the Pacific Ocean, and subsequent colonization of Australia in 1871, using already established weed species of Asclepiadaceae (Zalucki & Clarke 2004).

Alternatively, the transplantation by humans of host plants to new regions of the world (as ornamentals or crops) can 'prime' these areas for colonization should a suitable butterfly accidentally or intentionally be introduced there. Such butterfly species, in effect, are 'chasing' their host plants. This is the case with *B. exilis* in both Hawaii and the Arabian Gulf.

Over the last 100 years, with increasing international trade and travel, several butterflies have managed to hitch lifts to new regions. The most recent parallel to *B. exilis* has been the establishment of *Cacyreus marshalli* Butler, 1897 in southern Europe. This South African butterfly feeds on wild geraniums (*Pelargonium* spp.) in South Africa, cultivated forms of which are/were widely grown throughout the Mediterranean region. This butterfly was first recorded from Mallorca in 1989, having probably been brought in by some nice blue-rinse lady from Cape Town visiting friends or relatives and bearing a cutting of her favourite geranium, or perhaps via the ornamental flower trade. It has since spread around the coast of Morocco, Spain and France, and down Italy as far as Rome. Vagrants have even been found as far north as Belgium and the UK (Baufeld 1993).

Others are *Pieris rapae* (Linnaeus, 1758), which was introduced to North America in the 1860s (and into Australia around 1937); *Thymelicus lineola* (Ochsenheimer 1808), introduced into Ontario, Canada in 1910 and now found as far west as British Columbia; *Pieris brassicae* (Linnaeus, 1758), which established itself in Chile in the

early 1980's and then in Cape Province, South Africa, in 1994. The banana skipper (*Erionota thrax* (Linnaeus, 1767)) has been accidentally introduced into Guam (1956), Mauritius (around 1970), Hawaii (1973) and New Guinea (1983), where it is a serious pest of bananas. Many species have been introduced to Hawaii, including *B. exilis*. Two butterflies were deliberately established to control the exotic weed *Lantana camara*, namely *Strymon bazochii* (Godart, 1824) (in 1902) and *Tmolus echion* (Linnaeus, 1767) (in 1902), and butterfly enthusiasts took advantage of the widespread establishment and cultivation of *Passiflora* and *Citrus* to introduce both *Agraulis vanillae* (Linnaeus, 1758) (around 1977) and *Papilio xuthus* Linnaeus, 1767 (around 1971).

The most recent exotic colonisations that have come to our attention are *Papilio demoleus* Linnaeus, 1764 in the Caribbean (Guerrero et al. 2004) and *Dryas iulia* (Fabricius, 1775) in Thailand (Pittaway, pers. obs. 2005). The latter Neotropical species has established itself in Phuket (in 2004) and is now spreading on *Passiflora foetida*, itself an alien which can grow in profusion on any derelict site. The invasive nature of this plant has also helped *Acraea violae* (Fabricius, 1775) extend its range; Larsen saw huge numbers in the centre of Bangkok in 2004.

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